

Possible eRHIC-related studies

V. Ptitsyn

Motivation for beam experiments

- Verify some of approaches and techniques used in the eRHIC design.
- Emulate beam dynamics effects expected in eRHIC.
- Get better quantitative knowledge of hadron machine characteristics used in the design of eRHIC systems.
- Test the feasibility of eRHIC beam parameters.

Proton beam parameters

	eRHIC (2014)	Achieved at RHIC
Energy, GeV	100-250	Runs at 31, 100, 250 (255) GeV
Number of bunches	111	111
Bunch intensity, 10^{11}	0.3	1.8 (at store)
Normalized 95% emittance, $1e-6$ m	1.6	~15-20 mm*mrad at the store
beta*, cm	5	65
rms bunch length, cm	5	~50 cm
Store polarization	70%	~62% at 100 GeV, ~58% at 250 GeV

eRHIC proton bunch intensity is well below that achieved at RHIC

- Eliminates problems related with the high peak beam current: cold beam pipe heating, BPM cable heating, ...

Baseline design 2014:

Machine cost saving at the acceptable luminosity ($10^{33}\text{cm}^{-2}\text{s}^{-1}$)

Clear path for the future luminosity upgrade :

increase proton bunch intensity ($3\cdot 4 \times 10^{11}$) , $L > 10^{34}\text{cm}^{-2}\text{s}^{-1}$

Baseline design beam parameters

	e	p	$^2\text{He}^3$	$^{79}\text{Au}^{197}$
<i>Energy, GeV</i>	10	250	167	100
<i>CM Energy, GeV</i>		100	81.7	63.2
<i>Bunch frequency, MHz</i>	9.4	9.4	9.4	9.4
<i>Bunch intensity (nucleons), 10^{11}</i>	0.33	0.3	0.6	0.6
<i>Bunch charge, nC</i>	5.3	4.8	6.4	3.9
<i>Beam current, mA</i>	50	42	55	33
<i>Hadron rms normalized emittance, $1\text{e-}6\text{ m}$</i>		0.27	0.20	0.20
<i>Electron rms normalized emittance, $1\text{e-}6\text{ m}$</i>		20	22	36
<i>β^*, cm</i>	5	5	5	5
<i>Hadron beam-beam parameter</i>		0.015	0.014	0.008
<i>Space charge parameter</i>		0.006	0.016	0.016
<i>Electron beam disruption</i>		4.3	5.2	1.9
<i>rms bunch length, cm</i>	0.4	5	5	5
<i>Polarization, %</i>	70	70	70	70
<i>Peak e-nucleon luminosity, $\times 10^{33}, \text{ cm}^{-2}\text{s}^{-1}$</i>		1.1	2.1	1.3

eRHIC-related studies

1. IR design:
Dynamic aperture compensation in 90 degree lattice, ATS beta-squeeze.
2. Beam-beam interactions:
Effect of electron beam jitter (e-Lens); Control of s^* .
3. Interplay of space-charge and beam-beam effects.

Studies for the eRHIC luminosity $10^{34}\text{cm}^{-2}\text{s}^{-1}$

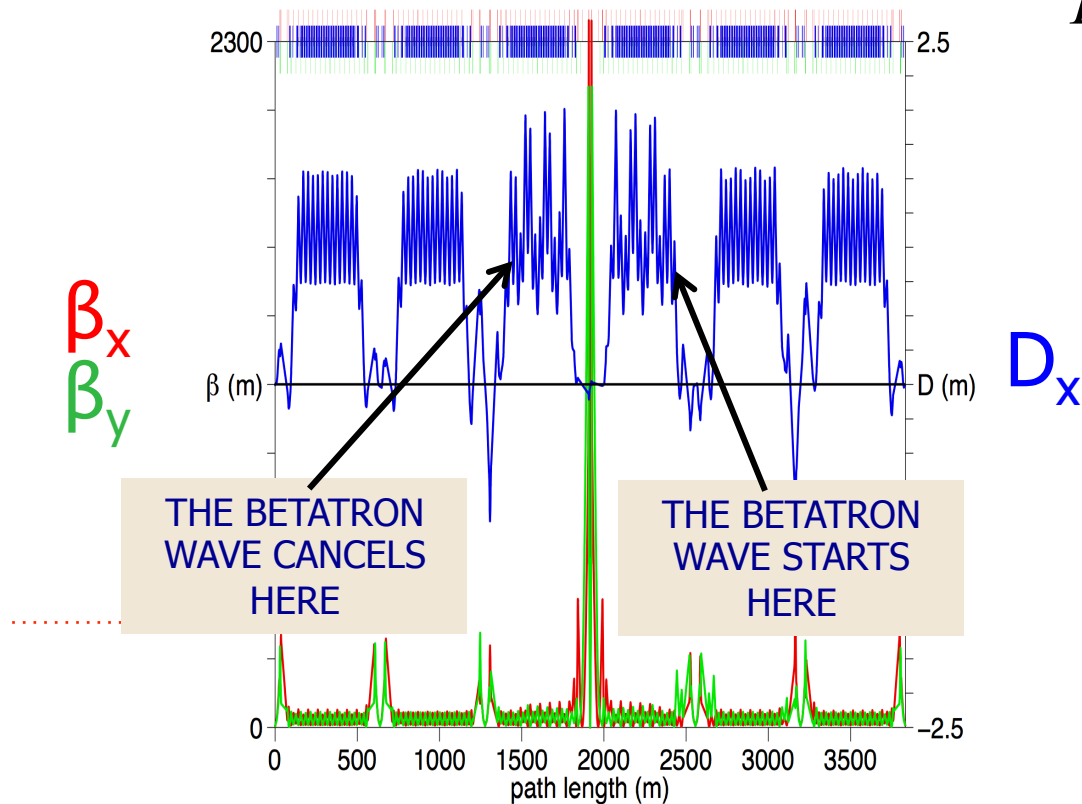
4. Study of bunch length limits.
5. Longitudinal impedance and the microwave instability threshold
6. Transverse impedance and the intensity limits, feedback systems
7. Intensity limits: beam instrumentation, BPM cable heating

Interaction Region design: ATS method

eRHIC IR design: ATS method was proposed to achieve 5 m beta*.

Closed beta-wave is organized in two arcs (around the IR)

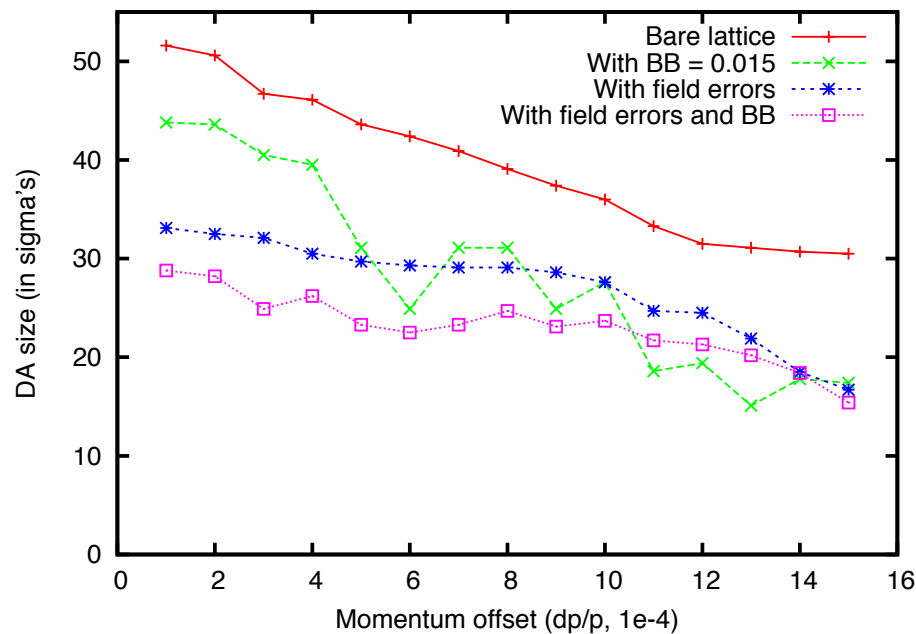
D. Trbojevic



Verification of the technique at present RHIC would be great. If successful, can be used at RHIC.

Hadron chromaticity correction

Y. Jing, D. Trbojevic, Y.Luo



90 degree lattice.

DA aperture optimization:

- existing sextupole families
- minimization of the resonance driving terms

The technique can be verified with 90 degree lattice in RHIC

Beam-beam interactions

Y. Hao

Control of beta-function minimum location is important:

Change of s^* in eRHIC by 10 cm \rightarrow $\sim 30\%$ luminosity loss

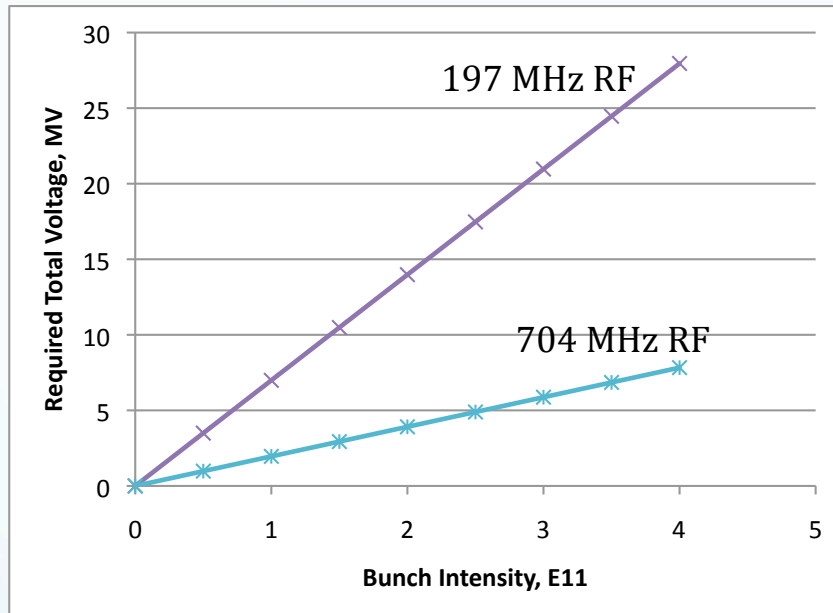
Studies to demonstrate the possibility of the s^* control on the scale of several cm are needed

Effect of fluctuations of electron beam parameters (offset, intensity, beam size) on the hadron beam.

e-Lens commissioning and studies would help to learn about this effect and verify the eRHIC expectations.

2-3 μm rms electron position error in IP is expected

RHIC Longitudinal Impedance



For longitudinally cooled beam in eRHIC the microwave instability is possible.

The longitudinal impedance defines the requirements for the RF system (harmonic and voltage) needed to prevent the instability .

It would be good to verify that measurement a decade later

The plot shows the required RF voltage based on the longitudinal (broadband) impedance 3 Ohm.

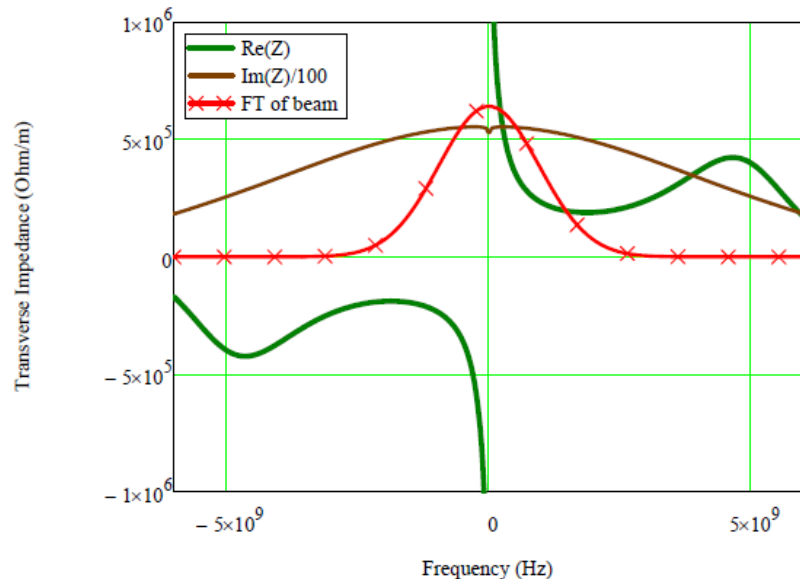
This is the measured value of the impedance:

M. Blaskiewicz, J. M. Brennan, P. Cameron, and W. Fischer.

"Longitudinal Impedance Measurement in RHIC." *EPAC 2002*

(the synchrotron tune shift versus the bunch intensity)

RHIC transverse impedance



Transverse impedance model is used (G.Wang, M.Blaskiewicz) to evaluate eRHIC transverse instabilities.

Both multi-bunch and single bunch transverse instabilities are observed in eRHIC studies (for $10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ luminosity)

Better knowledge of the RHIC transverse impedance would lead to better definition of the remedies:
octupole strength or feedback system parameters.

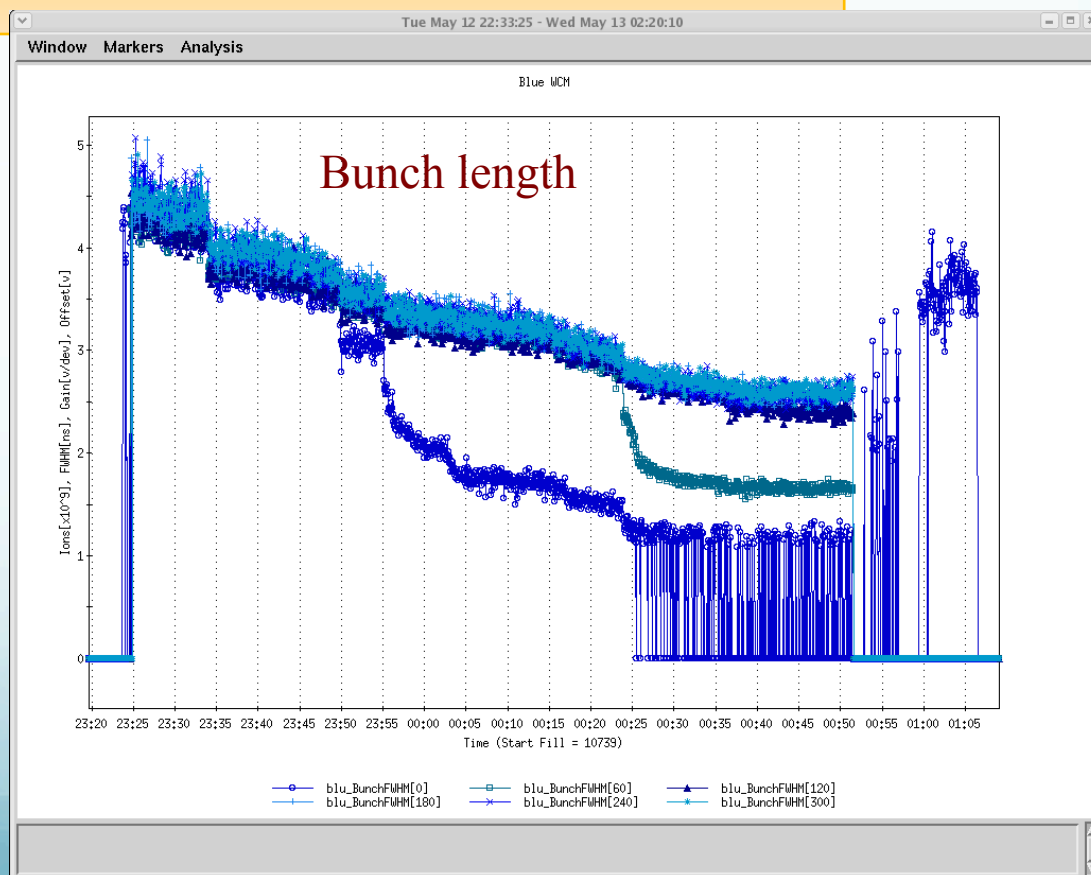
Study of bunch length limits

Goals:

- To identify and observe effects which may put limits on the minimum bunch length in RHIC.
- To distinguish the limitation coming from resistive wall heating and electron cloud (vacuum, pipe heating) and identify the heat load on the beam pipe from both effects.

Approaching transition
using gammaT quads.
Run-9 APEX studies.

Conclusion: need to automate
process and use feedbacks
(tune,coupling,orbit)



Plan for bunch length limit studies with proton beam

- Inject the proton bunches with intensities about $2\text{-}2.5 \times 10^{11}$.

Use 28 MHz RF system with highest possible voltage and, possibly, quad pumping technique in AGS. (197 MHz RF?)

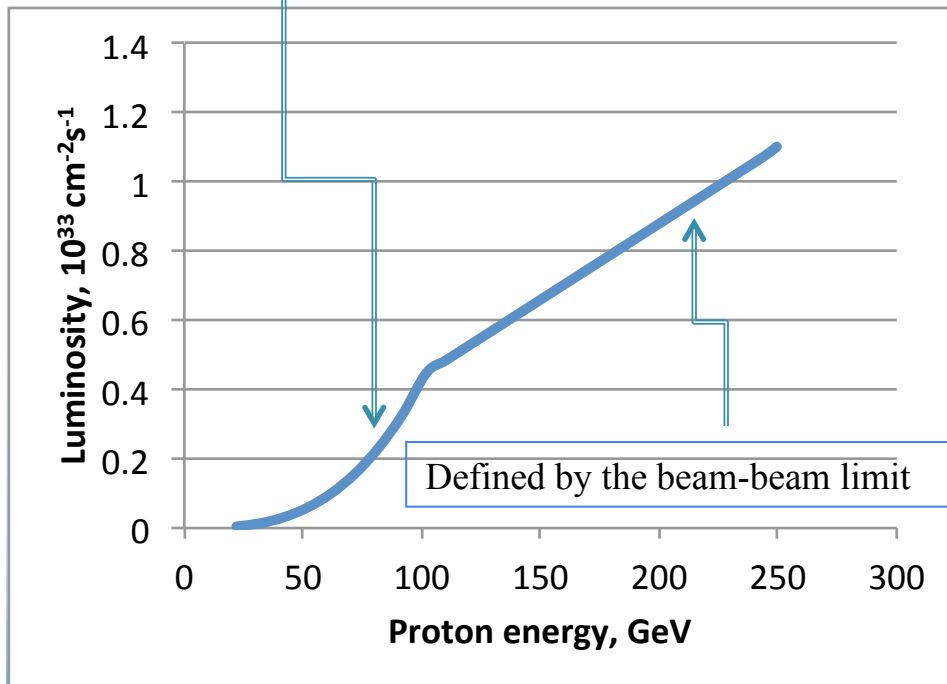
- Use a slow ramp with tune and orbit feedbacks:
 - Take advantage of the new Yellow beam lattice with higher gammaT energy.
 - Initial part of the ramp: ramping the gammaT quad settings, with corresponding tune corrections.
 - Second part of the ramp: slow (~few minutes) deceleration to the transition energy
- Record cryo-temperatures, vacuum conditions, transverse and longitudinal beam sizes (emittances).
- Possible complications: increased space charge effect; BPM cable heating
- Make ramps:
 - with small number of bunches of different intensity to look at the instabilities and the space charge effects
 - with 109 bunches: to look at the pipe heating and EC effects

Luminosity energy dependence

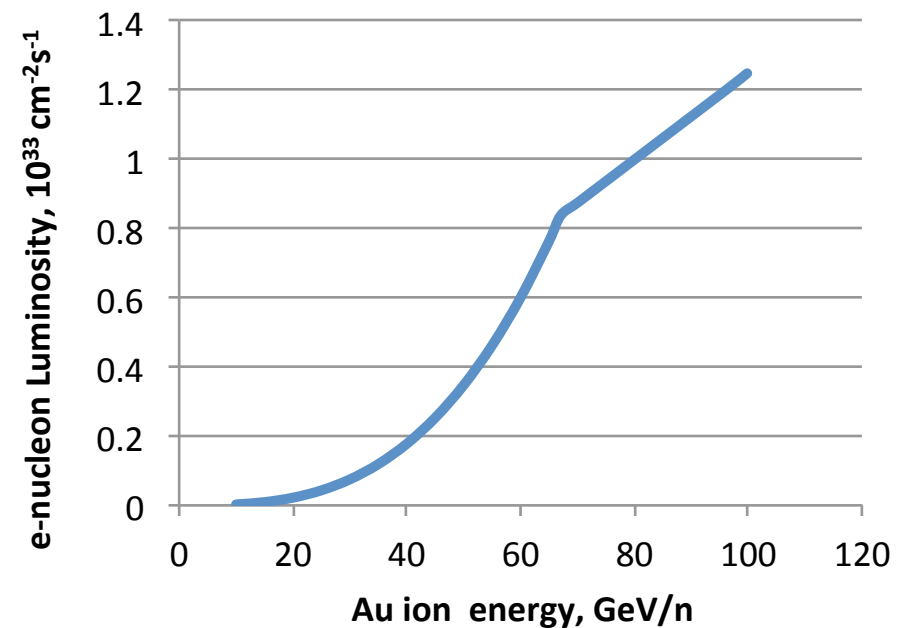
$$\Delta Q_{sp} \leq 0.035$$

Defined by space charge limit, reduced N_p

Limiting space charge parameter defines the luminosity at lower hadron energies



Electron-proton luminosity



Electron-Au nucleon luminosity

Interplay of space-charge and beam-beam effects

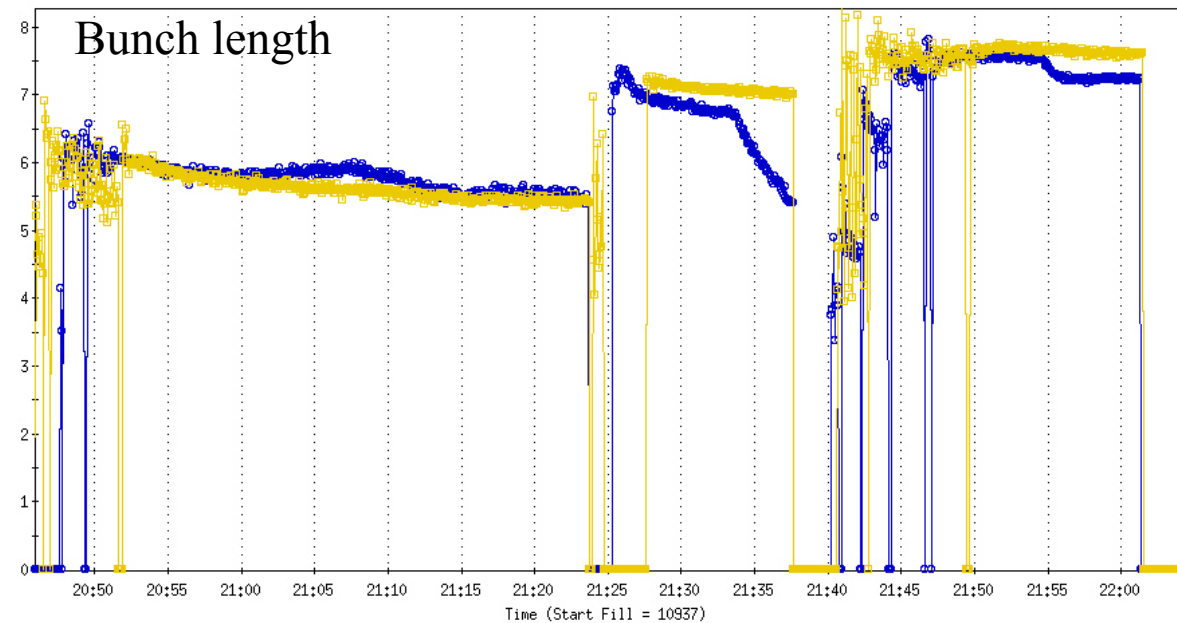
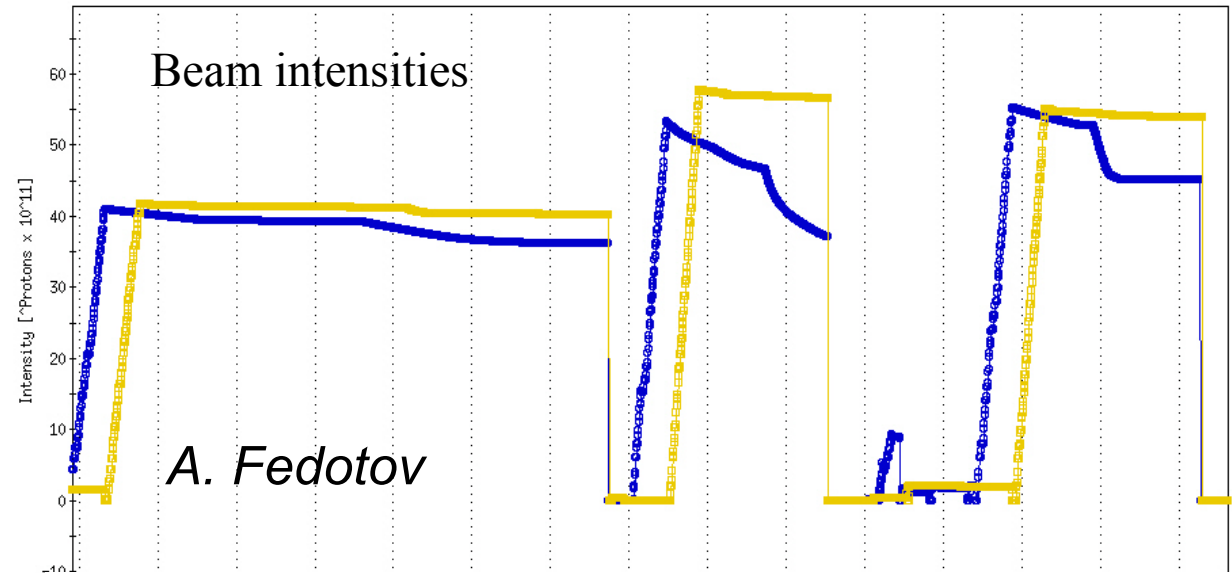
Protons
@ $\gamma=25$

$$\Delta p/p = 1.5 \cdot 10^{-3}$$

Losses are seen in the
longitudinal plane

In eRHIC:

$$\Delta p/p = 3 \cdot 10^{-4}$$



bo2-wcm3;bunchLengthM:valueAndTime yi2-wcm3;bunchLengthM:valueAndTime

Plan for space charge studies with proton beam

Remaining question:

-What would be the beam lifetime with the momentum spread more similar to the eRHIC value?

Suggested measurements with protons:

-Compare the beam lifetime obtained at different momentum spread (9 MHz versus 28 MHz RF system) but at the same space charge and beam-beam parameters.

-Do the measurement at (0.69,0.68) working point area; compare the beam lifetimes with exchanged Blue and Yellow working points.

-If studies with for the Integer working point are planned, take the advantage of machine tuning done during that studies and do the measurement at that working point area.